Demonstration Abstract: Upper Body Motion Capture System Using Inertial Sensors

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***Abstract*—Motion capture plays an important role in interactive gaming, animation, film industry and navigation. The existing camera-based motion capture studios are expensive and require a clear line of sight; hence they cannot be applied to ubiquitous applications. With the rapid development of low-cost MEMS sensors and sensor fusion techniques, the inertial sensor based motion capture systems are attracting a lot of attention because of the seamless deployment, low system cost and the comparable accuracy they provide. In this paper, we demonstrate a wireless real-time inertial motion capture system.**

Keywords—motion capture; inertial sensors

I. Introduction

Motion capture plays an important role in the fields of gaming, filmmaking, animation, medical applications and navigation. The existing commercial motion capture systems are mainly based on multiple high speed and high resolution cameras, *e.g.,* Vicon [1] and OptiTrack [2]. These techniques typically require cameras to be mounted in a controlled environment and can only capture markers in clear view, resulting in a poor rendition of many activities. Further, the infrastructure may not be available at all desired locations or may be expensive to implement. The low cost camera based system (*e.g.*, Kinect [3]) suffer from similar limited sensing range and moreover, it cannot sense certain degrees of rotation (*e.g.*, twisting of the arm). Instead, wearable sensors capable of capturing movements are gaining popularity due to their minimal cost, ubiquitous nature and their ability to provide sensing opportunities at any time and place.

II. System Overview

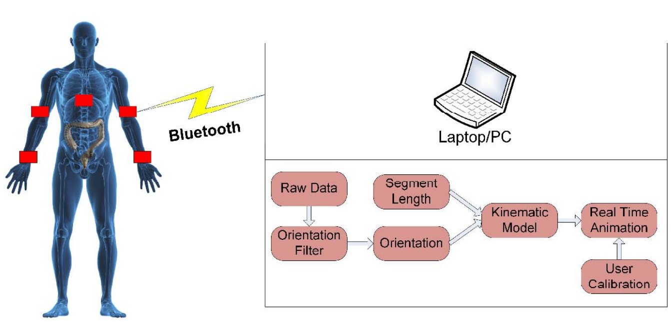

Fig. 1. Motion capture system overview.

Our upper body motion capture system is shown in Fig. 1. Five motion sensors, represented by red rectangles, are attached to the left forearm, left upper arm, right forearm, right upper arm and the spine. The raw accelerometer and gyroscope data is transmitted to a laptop/PC wirelessly via Bluetooth. The static noise of gyroscope is removed via calibration. The data is fused by an orientation filter to provide accurate orientation estimation. The orientation data, combined with the predefined body segment length, is applied on a kinematic mesh model to represent the exact movements performed by the user. A real time 3D rendering software developed using Ogre3D [4] is used to animate the upper body motion. A Bluetooth network can support up to seven slave devices, hence we only created the upper body motion capture system, covering five upper body segments. The orientation tracking error will accumulate as the time passes. A user calibration command can be sent to the PC to reset the orientation of the five sensors.

A. Hardware Description

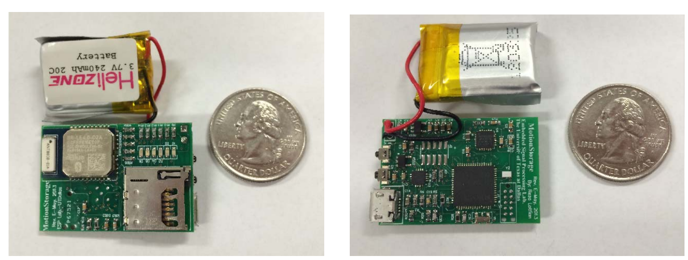

Fig. 2. Hardware component: (left) top view, (right) bottom view.

Fig. 2 shows the 9-axis motion sensor with the size 1”x1.5” that was designed and developed in our laboratory [5]. An InvenSense MPU9150 9-axis MEMS sensor is used to measure the 3-axis acceleration, 3-axis angular velocity and 3-axis magnetic strength. A Texas Instrument 16-bit low power microcontroller MSP430F5528 is used as the central processor. Serial interface I^2C between MSP430 and MPU9150 enables control command transmission from the microcontroller to the MEMS sensor and data transmission from the MEMS sensor to the microcontroller. Similarly, UART is implemented between the Bluetooth module and microcontroller. Both a dual mode Bluetooth unit CC2541 and a microSD module are available on the board. The user can choose to stream the data to a PC/tablet for real-time processing or log all the data on a microSD card for long-term movement monitoring. A charging circuitry is included.

III. WORKING PRINCIPLES

A. Orientation Filter

An orientation filter is used to calculate the orientation of each sensor frame with respect to the world frame [6]. The gravity and magnetic field measured by accelerometer and magnetometer are used as reference vectors in vertical and horizontal direction with respect to the earth's surface. A gradient descent algorithm is used to estimate error measured by the gyroscope. This algorithm supports both 6-axie inertial measurement unit (IMU) and 9-axis MARG (Magnetic, Angular Rate, Gravity) sensor array, which includes 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer. Due to the large indoor magnetic interference in our laboratory (*e.g.*, the existence of metal pipes under the floor), we did not use the magnetometers.

B. Kinematic Model

The human body is modeled as a hierarchical structure [7]. In our system, the five sensors are attached to the spine, left should, left hand, right shoulder and right hand. The spine is the root joint and is the parent for the left and right shoulders while the left and right shoulders are the parents for the left and right elbows. The orientation data from each sensor is assigned to each corresponding joint. Combined with the predefined segment length, the skeleton mesh is guided and the users' movements are captured and animated.

IV. EXPERIMENTAL RESULTS

Fig. 3 shows three snapshots of our motion capture system in action, and the Ninja avatar displayed on the screen shows the movements of the user captured by our system.

A. System Performance

In order to evaluate the performance of the system, we performed a set of experiments to measure the time it takes for the system to develop a notable error for different movements with different speeds, denoted as T_{error}. A state of "notable error" is reached when the animated movement contradicts physical human kinematics. For example, the hand is shown to be going through the head when the user is performing 'touching head' movement. The time T_{error} is measured while the user continues to repeat the same movement. The results are shown in TABLE I. The user can recalibrate the system to the natural standing pose by pressing a button on a laser pointer whenever the system experiences a notable error.

TABLE I. Notable Error Generation Time for Different Movements

Slow Movements	T_{error} (Minutes)	Fast Movements	T_{error} (Minutes)
Walking	5.4	Running	2.4
Touching Head	6.8	boxing	1.2
Waving Hand	7.1		

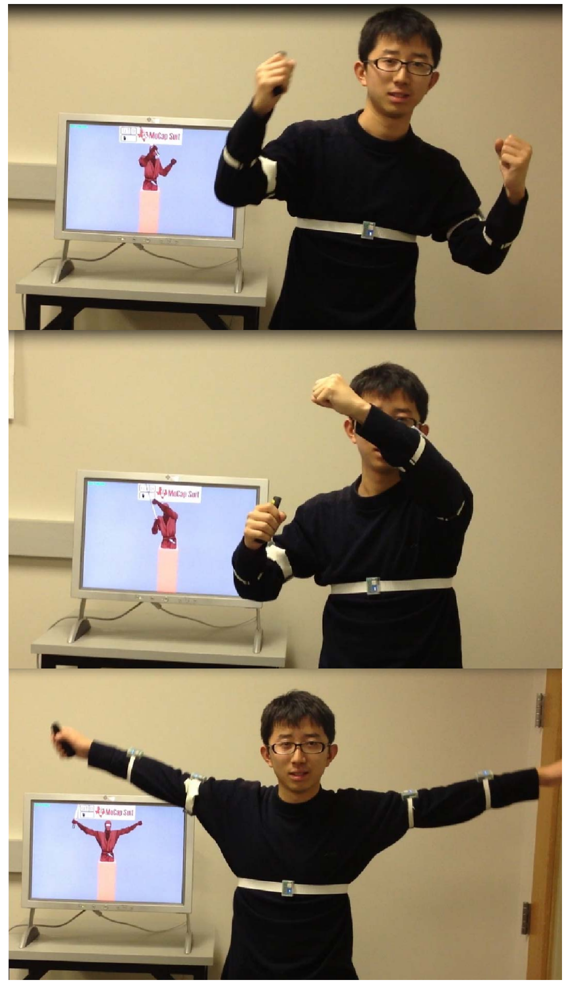

Fig. 3. Snapshots of motion capture system.

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